




Article

Impact of the COVID-19 Pandemic on the Energy Use at the University of Almeria (Spain)

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Abstract: The COVID-19 pandemic has caused chaos in many sectors and industries. In the energy sector, the demand has fallen drastically during the first quarter of 2020. The University of Almeria campus also declined the energy consumption in 2020, and through this study, we aimed to measure the impact of closing the campus on the energy use of its different facilities. We built our analysis based upon the dataset collected during the year 2020 and previous years; the patterns evolution through time allowed us to better understand the energy performance of each facility during this exceptional year. We rearranged the university buildings into categories, and all the categories reduced their electricity consumption share in comparison with the previous year of 2019. Furthermore, the portfolio of categories presented a wide range of ratios that varied from 56% to 98%, the library category was found to be the most influenced, and the research category was found to be the least influenced. This opened questions like why some facilities were influenced more than others? What can we do to reduce the energy use even more when the facilities are closed? The university buildings presented diverse structures that revealed differences in energy performance, which explained why the impact of such an event (COVID-19 pandemic) is not necessarily relevant to have equivalent variations. Nevertheless, some management deficiencies were detected, and some energy savings measures were proposed to achieve a minimum waste of energy.

Keywords: energy consumption; COVID-19; energy savings; energy performance; university buildings; sustainability



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1. Introduction

The international energy market showed different fluctuations inflicted by the COVID-19 pandemic situation in 2020; energy demand and oil prices plummeted in early March of 2020 due to the COVID-19 outbreak throughout the globe when governments were urged to ban travel on a national and international level [1]. The lockdown of businesses and commerce decelerated world trade, which caused a global recession in 2020, the world gross domestic product (GDP) shrunk by 4.4% [2]. On the other hand, global electricity demand fell by 5%, which led to a positive impact on the environment, and much cleaner air quality was reported on most pollutant cities, and satellite imagery showed that the urban heat island had been reduced in several metropolitan areas [3]. Moreover, schools and universities were closed in most countries. Therefore, the educational system had to adapt to this situation, and online learning through video conferences was adopted widely [4]. As a result, the energy use in buildings destined for education decreased: in

the USA the energy consumption in buildings declined by less than 10%, while gasoline and jet fuel drastically fell by 30% and 50%, respectively, from March to June of 2020 [5]. Furthermore, the data collected in more than 30 countries showed that the fall of electricity consumption in public, industrial, and commercial buildings was resisted by an increase in residential buildings, which went up to 27% higher as more people had to work and study from home [3]. The severity degree of lockdowns and their duration were the main factors that affected the energy demand, for instance, in one month of confinement, the energy demand decreased by 20% on average and was reduced by 1.5% on a yearly basis [3]. Nevertheless, as most countries started to soften confinement measures, during June, the electricity demands were 10% lower than in the same month of 2019, and then it went down in July to 5% lower than the level of the same month of the previous year, with the weather corrected in the following countries (Great Britain, India, Spain, France) [6]. In EU countries, the electricity demand started to recover to levels close to the ones reached in 2019 during August; afterward, the demand steadily decreased in the following months as the restriction measures were implemented once again [6]. However, the end of the year was marked by energy demand levels that surpassed the ones in the previous year after a weather adjustment [6]. This happened mainly in economies that depended heavily on the industry, such as China, where factories were able to maintain their industrial activity by following the preventive and safety protocols that were recommended by special authorities [7]. Thus, confinement measures had a less significant effect on the overall energy demand, since the industry sector alone accounts for more than 60% against 10% for services of the country's total consumption [7], while the impact was much heavier in the USA where the industry sector accounts for only 20% and the services account for 40% and for Europe, the impact was even greater since the services sector plays a fundamental role in its economy [8].

The global electricity supply dropped by 2.6% in the first quarter of 2020 compared with the same period in 2019 [9], while electricity generation from renewable sources increased by 3%. This jump is mainly due to new investments in wind-solar photovoltaic power over the past year [10]. This increase came by and at large at the cost of gas and coal as those two sources still generate roughly around 60% of the global electricity supply [11]. The share of electricity generated by nuclear power also declined by 3% because fewer reactors were operational in the first quarter of 2020 [12]. Although the fossil fuel industry fell by only 2.8% in generating electricity, its market showed unusual fluctuations such as a negative price of oil in the US market; other markets switched from gas to coal because of the cheap prices [3,11,13]. As a result, the coal-fired power fell by 8% in comparison with the first quarter of 2019 [3].

Even though the decline of the world electricity demand in 2020 caused a reduction in CO₂ and greenhouse emissions and was responsible for improving the quality of air and water, we are still far from reaching the Paris climate change agreement goals [14,15]. Moreover, this economic crisis threatens to delay investments in clean energy, the unemployment rate grew to unprecedented levels, and many families lost their income. This only makes it even harder for households to benefit from reliable and affordable energy, which exacerbates the issue of energy poverty [5]. The Spanish Ministry for the Ecological Transition and the Demographic Challenge (MITECO) initiated measures to ensure electricity, water, and gas supplies in the residential sector. This action came as an emergency response to the lockdown imposed in early March of 2020. The Spanish government implemented regulations to temporarily suspend the jurisdictions that allow disconnecting the electricity supply for non-payment until the end of the emergency state. Then it proposed partial payment as a solution to pay off the bills in an extended period of time for households that were mostly affected by the outbreak. These jurisdictions were applied to the residential sector and only on the first property. Among other support measures, the Spanish government put on hold any upward update of the domestic electricity and gas prices by supporting the default tariff during the emergency state [16]. The renewal of their social tariff deadlines was delayed and enlarged the number of households eligible for the

electricity social tariff. The beneficiary list also included self-employed people who had to stop their activity or saw their income shrink by more than 75% [16].

The International Energy Agency has been urging nations for actions to save the enormous energy loss due to inefficiency [17]. Energy savings in buildings are usually perceived mainly from thermal insulation and indoor lighting standpoint, except that energy efficiency is about all the operating components of a building. Furthermore, there is an important amount of savings that could be made in other areas such as plug load and occupant behavior [18]. In the USA, the electricity consumption of plug and process loads (PPLs) is responsible for 33% of the commercial building, and the consumption of the heating, ventilation, and air cooling (HVAC) system is not included in this ratio since it is integrated into a centralized system [19]. The percentage of the plug load is expected to grow in the future since our buildings use more electrical equipment. In 2011, the Department of Energy's National Renewable Energy Laboratory (NREL) implemented an energy-saving program with a national strategy for commercial buildings in order to reduce the energy consumption without affecting the functionality of their facilities, and they were able to reduce the electricity consumption by over 30% of the plug load ratio [20].

Investing in energy efficiency programs and energy management in buildings is crucial for universities to promote sustainability and raise awareness among the academic community about our carbon footprint [21]. University campuses use energy in a different way than residential buildings, and their consumption pattern is more complicated since it depends on many different factors such as physical characteristics of the facilities, occupancy rate; heating, ventilation, and air cooling (HVAC); indoor lighting; outdoor temperature; number of computers; laboratory materials; and plug loads [22,23]. It was estimated that plug loads were responsible for 32% of the total energy use of the Stanford University's campus, in a study case that included 220 buildings that evaluate around 50 GWh in yearly electricity consumption [24]. In addition, electric lighting accounted for 20% to 30% of the electricity consumption in office buildings and consumed, on average, about 14% of energy in schools in the USA [25,26].

This case study aimed to measure the impact of the COVID-19 pandemic on the energy consumption of the University campus during the period of lockdown. In a previous study, we were able to prove that the weather factor affected the total energy consumption of the campus more than the occupancy rate factor [27]. The confinement situation gave us the opportunity to evaluate the energy performance of the university campus when there was practically no human activity. Furthermore, analyzing the data during this period allowed us to understand the dynamics of the electricity consumption inside the campus and how we could minimize energy loss. Many types of equipment remained operational during the lockdown, like laboratory materials, fridges, ultra-freezers that maintained temperatures as low as $-80\text{ }^{\circ}\text{C}$, security systems such as sensors and cameras, and other equipment such as vending machines, exterior lighting, and internet and telecommunications equipment. This case study could be applied to other universities if similar data were available. It also could inspire other researchers, for example, to measure the impact of unplugged equipment during off days of the year. This quantity could be often underestimated, but when you operate hundreds of electrical materials in the university, it could have a considerable impact on energy use in the long run.

2. Materials and Methods

The University of Almeria campus accounts for 33 buildings and spreads on a surface of 170.000 m^2 . The campus is responsible for average electricity consumption of approximately 8 million kWh each year.

The dataset is composed of the total energy consumption on a monthly basis in the period of 2011–2020 (Table 1), the energy consumption on a monthly basis in 2020 of every building according to its categories (Table 2), and the energy consumption on an annual basis according to the buildings and their categories (Table 3).

The period studied in this paper is the year 2020, which could be divided into three parts: the first one is the pre-outbreak period; the second one, starting from March until August when the occupancy rate at the campus was almost 0%; and the third part is when only 50% of the staff and research students were allowed the access the campus facilities.

Administration buildings (Figure 1) comprise facilities like offices, meeting rooms, seminar rooms, and lecture halls. These facilities host theoretical and practical training. Most of the administration buildings were inoperative during the period of lockdown. This category decreased by almost a third of its share, compared with 2019.

Building (1), the University presidency, is a four-floor building with a gross floor area of 5880 m². This facility is composed of offices, meeting rooms, seminar rooms, and lecture halls. Building (2), the Central Administrative Services, is a two-floor building with a gross floor area of 11,430 m². This facility is composed of offices and computer rooms, classrooms, and cafeteria restaurants. Building (18), the Department of Entrepreneurial and Economical Science, is a three-floor building that has a gross floor area of 2620 m². This facility is composed of offices, seminar rooms, classrooms, and computer rooms. Building (19), the Department of Human and Social Science, is a three-floor building with a surface of 8290 m². This facility is composed of offices, classrooms, seminar rooms, and computer rooms. Building (20), the Department of Juridical and Law Science, is a three-floor building with a gross floor area of 2450 m². It is composed of offices, classrooms, and seminar rooms. Building (21), the Department of Education, is a two-floor building with a surface of 4605 m². It is composed of seminary rooms, teaching and computer rooms, and solar energy workshops. Building (8), the Central building Cafeteria, is a three-floor building with a gross floor area of 3994 m². This facility is composed of main offices and a cafeteria.

The teaching and seminary rooms (Figure 2) comprise facilities like classrooms, lecture theatres, computer rooms, and these facilities usually contain a high number of occupants. Although the teaching and seminary rooms were empty during the larger part of 2020, this category consumed the equivalent of 72% of its share of the electricity consumption of 2019. Building (4) is a seminar building that is composed of one big lecture hall that spreads on a surface of 1002 m²; events such as conferences, seminars, and ceremonies are frequently hosted in this facility.

Buildings (5), (15), and (3) are teaching facilities composed of three floors with respective surfaces of 5612 m², 4118 m², and 5585 m². These buildings are mainly composed of classrooms and few computer rooms.

Table 1. Monthly evolution of energy consumption of the university campus per year.

Month/Year	Campus Monthly EC (kWh)									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
January	722,623	717,867	706,880	708,499	765,785	702,918	773,539	770,454	776,306	768,904
February	689,088	746,940	672,895	657,712	737,049	693,787	652,036	725,147	684,468	681,448
March	729,218	685,622	681,843	689,979	728,747	666,108	706,072	716,676	682,224	576,683
April	573,686	571,444	630,393	597,792	640,762	644,299	580,052	680,127	607,203	416,742
May	700,648	687,262	644,661	667,437	717,944	672,034	713,215	730,265	737,216	450,385
June	762,909	765,368	656,218	696,597	798,527	761,444	936,273	740,233	730,448	519,453
July	737,705	724,290	707,900	703,602	877,181	776,462	801,608	704,690	788,081	705,993
August	550,274	527,979	487,813	513,183	597,359	545,341	617,208	608,966	576,199	549,028
September	760,301	6933	731,827	753,425	785,407	837,467	821,574	645,724	816,350	666,382
October	693,375	654,832	727,983	710,872	721,047	742,409	780,345	699,640	764,269	634,500
November	640,273	632,938	647,683	671,644	623,533	685,437	705,548	757,993	699,365	589,695
December	621,586	629,833	627,630	683,565	616,653	645,593	691,188	872,744	661,745	584,675

Table 2. Energy consumption on a monthly basis in 2020 of every building according to its category.

Structure Category	Building Notation	EC (kWh)											
		January	February	March	April	May	June	July	August	September	October	November	December
Administration Office	1	15,513.00	14,207.60	11,061.30	10,785.70	18,578.20	22,494.00	26,905.60	17,793.60	24,893.5	21,040.00	17,817.50	15,892.80
	2	32,071.30	28,783.50	27,108.40	22,713.60	26,539.00	26,233.10	34,051.90	14,122.50	30,042.4	26,563.10	24,425.00	21,251.90
	18	5840.70	5062.30	5163.50	4402.00	5258.70	5234.70	5604.70	3480.00	6126.3	5443.50	5142.90	4247.90
	19	25,104.80	25,112.50	23,555.60	13,312.20	16,240.70	21,120.90	26,483.00	6714.40	25,522.9	22,617.50	21,123.70	23,170.90
	20	5995.70	5755.00	5442.80	4560.90	4952.50	4427.90	4599.30	2178.50	4427.5	3619.20	3687.80	3308.40
	21	9166.50	7499.50	7212.10	5895.40	6475.80	6016.40	6545.20	2331.80	6976	7071.70	7009.20	5972.00
	8	15,021.70	13,602.40	11,353.80	9328.30	9187.60	8631.80	11,880.00	2568.50	10,301.6	8761.10	8739.00	8441.20
Teaching and Seminary Room	3	20,717.60	21,665.20	17,524.80	11,203.80	12,367.50	15,839.7	19,739.50	19,166.20	21,948.6	29,668.40	19,664.30	15,949.20
	23	15,173.50	13,073.20	10,527.90	8323.70	9161.50	10,291.8	14,760.60	12,463.80	13,278.6	12,487.90	12,699.60	12,139.20
	12	15,384.90	12,819.30	8268.80	4012.80	4628.20	4691.8	4487.40	3866.10	4520.8	8206.80	5377.50	4169.60
	5	12,218.00	11,163.80	7544.50	2058.40	2478.60	3081	5392.60	4492.80	4053.2	8416.10	4544.20	2592.20
	15	11,656.30	10,946.40	6880.70	1726.10	1991.30	2819.7	6292.90	2340.40	4115.5	9300.10	5868.90	3426.70
	4	734.30	937.90	506.20	127.10	129.60	177	139.70	135.00	734.5	879.30	669.50	561.00
	11	3367.80	2653.00	2692.90	2180.30	2295.40	2094.9	2591.90	2117.50	2352.6	2875.30	2880.20	2615.90
Research Building	9	17,186.50	15,221.50	12,664.70	9514.40	10,321.40	11,549.6	15,618.40	14,503.70	16,249.6	15,515.50	10,526.20	17,079.60
	30	72,688.40	69,386.60	73,735.50	69,867.90	74,131.80	73,851.9	75,587.90	73,197.50	70,410.9	73,430.80	72,935.50	74,235.20
	28	36,671.40	31,161.70	23,791.40	17,159.70	21,044.00	24,415.4	40,093.20	25,034.60	29,321.4	25,161.40	28,067.80	29,084.40
	29	57,178.70	58,173.40	62,339.10	54,599.00	60,793.50	64,173.3	75,002.00	61,692.90	53,543.7	50,239.70	55,223.10	45,242.30
	16	18,895.40	17,545.60	17,359.00	15,808.30	17,281.90	17,449.4	22,069.80	21,134.00	18,377.8	16,399.30	15,428.30	15,553.20
	31	18,501.10	16,496.00	10,768.10	4938.50	6992.50	16,836.3	21,635.00	7605.20	18,135.5	16,646.50	14,416.40	12,632.70
	24	47,451.80	43,088.80	47,648.90	43,917.00	49,106.60	51,407.6	57,599.00	43,820.80	56,465.7	53,811.50	51,356.60	50,985.80
	13	64,815.10	59,686.70	48,958.30	37,050.60	41,733.90	54,277.7	72,961.00	59,137.80	60,154.2	50,546.30	51,314.50	53,166.20
Library	26	82,203.40	56,936.30	34,094.40	12,450.80	12,147.60	23610.4	61,082.50	19,951.00	77,694.9	47,935.40	38,894.80	48,547.80
Sports Facilities	10	5237.10	5201.70	5554.50	4721.80	5453.40	4421.80	3367.00	1734.80	4470.5	6869.90	6104.70	5095.90
	7	26,880.80	27,641.70	29,684.00	27,615.10	30,635.40	29,217.00	32,554.10	6277.80	30,127.5	30,694.80	27,590.50	21,154.00
	17	4154.40	3722.20	3869.30	2237.70	1897.60	1592.40	1105.30	587.60	1749.5	3507.90	3979.50	2914.30
Restaurant Building	33	9183.60	7873.50	8795.50	7997.00	9664.50	11,067.90	11,697.50	10,502.10	11,314.1	9751.50	8245.50	9292.80
	6	7015.10	5700.50	6671.70	5529.00	8754.30	5288.30	3476.70	822.40	6168.2	8332.00	7427.50	4594.00

Table 3. Energy consumption on an annual basis according to buildings and their categories.

Space Category	Building	EC (kWh)	
		2019	2020
Administration Office	1	216,983	190,689
	2	313,906	224,364
	18	61,008	46,567
	19	250,080	146,965
	20	52,956	33,439
	21	78,172	51,630
	8	117,817	59,227
Teaching and Seminary Room	3	293,292	225,455
	5	132,495	68,036
	15	122,736	67,365
	12	145,368	80,434
	4	13,263	5732
	23	156,442	144,382
	27	299,717	241,767
Research Building	11	40,024	30,718
	9	183,607	165,952
	30	856,387	873,460
	28	340,777	331,007
	29	754,707	698,201
	16	225,731	213,302
	31	184,537	165,604
	24	503,052	596,661
Library Building	13	699,642	653,803
	26	927,397	515,550
Sports Facilities	10	58,234	47,041
	7	320,073	256,653
	17	31,318	15,522
Restaurant Buildings	33	115,386	72,393
	6	69,780	33,709

**Figure 1.** Different locations of the administration category.



Figure 2. Different buildings of the teaching and seminary category.

Building (12) is a teaching and seminary building. It contains lecture halls, teaching, and computer rooms, and this facility hosts different events from conferences to seminars and information technology training. Building (23) is the Center for Neuropsychological Evaluation and Rehabilitation (CERNEP) with a surface of 6605 m². It is composed of many facilities such as classrooms, rooms for practical medical exercising, and this center hosts different events from conferences to practical training and theoretical classes.

Building (27) is the Scientific and Technical Mathematics III, with a surface of 8618 m². It is composed of seminary rooms, teaching, and computer rooms, and this facility hosts different events from seminars, theoretical classes, and information technology training.

Research buildings (Figure 3) comprise facilities like classrooms, seminary rooms, computer rooms, laboratories, and these facilities host theoretical and practical training. Although the majority of research buildings were empty during an important period of 2020, nevertheless this category barely changed its consumption value and reached the equivalent of 98% of its share of electricity consumption in 2019. Building (9), the School of Engineering, is a three-floor building that has a gross floor area of 5487 m². This facility is composed of diverse engineering fields laboratories, offices, computer rooms, classrooms, and seminar rooms. Buildings (30), the Center of Information and Communications Technologies Services, is a three-floor building that has a gross floor area of 4301 m². This facility is composed of offices and computer rooms and an information technology workshop. Building (16), the Superior Council of Scientific Research, is a three-floor building that has a gross floor area of 2100 m². This facility is composed of offices, seminary rooms, and hydrology and geology-related laboratories. Building (28), the Scientific-Technical and Chemistry, is a three-floor building with a surface of 4828 m². This facility is composed of chemistry laboratories, classrooms, seminar rooms, and computer rooms. Building (29), the Center of Research, is a three-floor building with a gross floor area of 4975 m². It is composed of laboratories, and offices. Building (31), the Center of Solar Energy Research, is a two-floor building with a surface of 1072 m². It is composed of seminary rooms, teaching and computer rooms, and a solar energy workshops. Building (24), Technical and Science, is a three-floor building with a gross floor area of 3089 m². This facility is composed of seminary rooms, computer rooms and teaching rooms, laboratories, and offices. Building (13), Technical and Science II, is a three-floor building with a gross floor area of 12,341 m². This facility is composed of seminary rooms, computer rooms and teaching rooms, laboratories, and offices.



Figure 3. Different buildings of the research and laboratory category.

The Library building (26) (Figure 4) of the University has a gross floor area of 16,194 m². Its facilities include different structures such as study rooms, computer rooms, meeting rooms, staff offices, and common spaces.



Figure 4. Different views of Library building.

Restaurant buildings (Figure 5) provide services for the staff, students, and visitors. Building (6) is the official university restaurant. It is a one-floor facility with a gross floor area of 1280 m². Building (33) is a private bar-restaurant, it is a one-floor facility with a gross floor area of 1190 m², and these facilities are composed of kitchens, halls, terraces, and toilets.

The Sports facility (Figure 6), building (7), is an athletic swimming pool facility. Facility (17) includes a football stadium with an athletic running track and another smaller football stadium, and six tennis and paddle playing fields. Building (10) is a multi-sports hall that includes a gym, futsal, locker rooms, and showers.



Figure 5. Different locations of the restaurant category.



Figure 6. Infrastructure of the sports facilities.

3. Results

Figure 7 represents a histogram graphic that summarizes the evolution of the total electricity consumption on an annual basis from 2011 to 2020. The overall energy consumption has been varying in the range of 7.15 GWh–8.8 GWh, and it represents a gap of 10% between the minimum and the maximum value recorded. Furthermore, the year 2020 showed an unusual contraction due to the COVID-19 pandemic that hit Spain in the first months of 2020. This value is the lowest of the last ten years.

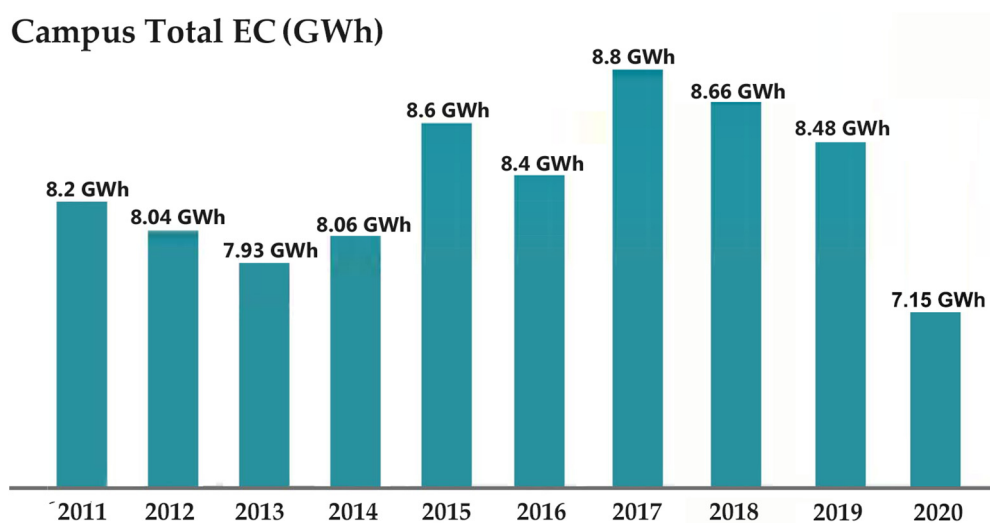


Figure 7. Campus annual consumption between 2011 and 2020.

Figure 8 illustrates the campus energy consumption on a monthly basis. During the first two months (January and February) both patterns of 2019 and 2020 were identical until the month of March that witnessed the COVID-19 outbreak in Spain. Then the 2020 pattern evolved below the levels of the previous year, it decreased sharply and simultaneously with the lockdown of the University in April. The gap began to narrow in August, this month was a summer break, and the number of occupants is at the lowest point for each year, and then the gap between the two graphics started to widen once again but not as much as in the period of the 0% occupant.

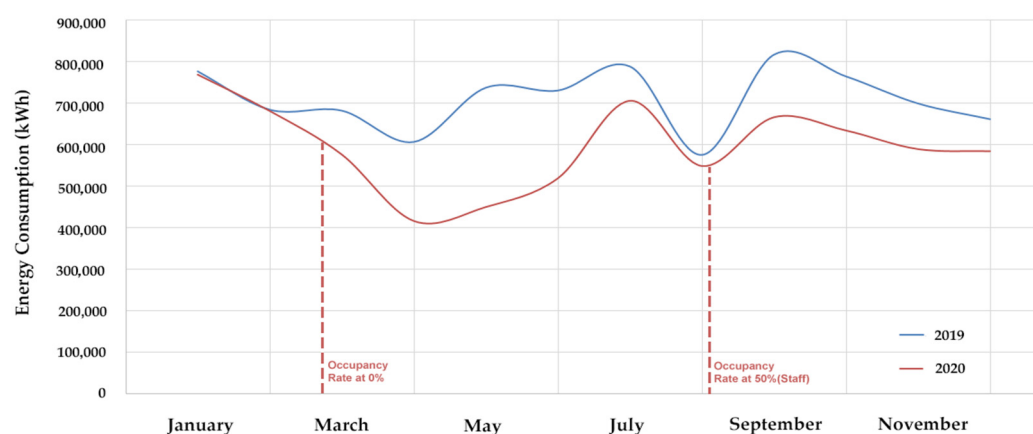


Figure 8. Patterns of monthly energy consumption of the University (2019–2020).

As Figure 9 illustrates that the research and laboratory category reduced its electricity consumption by 2% from 2019 to 2020. This means that the occupancy rate is uncorrelated with the EC of this category. Library buildings witnessed a significant decrease of 44%, which means that the presence of students and staff plays a key role in EC of this category. The teaching and seminary room electricity consumption share went down by 28% during the period studied, and sports facilities reduced their EC by 22%. The restaurant building's share of electricity consumption shrank by 42%. Administration and offices also showed a reduction of 31% in their share of the campus total EC. The EC gap in the same category between 2019 and 2020 varied from 2% to 44%. This disparity shows how much electricity consumption could differ from one category to another. These ratios do not reflect the manager's level of expectation since they are far from being as low as the occupancy rate, especially in categories like teaching and seminary, research, and sports. To find more persuasive reasons, we aim to go further to study the patterns of buildings within each category.

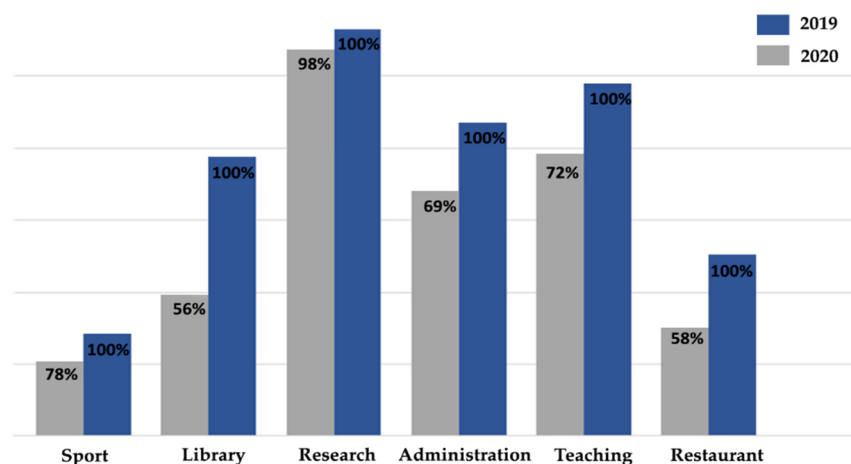


Figure 9. Energy consumption evolution by building category (2019–2020).

Administration buildings comprise facilities like offices, meeting rooms, seminar rooms, lecture halls. These facilities host theoretical and practical training. Most of the administration was inoperative during the confinement, except few particular cases: in June, few offices were reopened again, and, starting from September, the University adopted a policy of 50% presence of staff.

Figures 10 and 11 showcase that administration facilities have generally the same evolution through time: during the period from January to April, the administration facilities fell by a wide range of ratios that varied from 14% to 89%; however, this gap was driven by only one building (1) since the rest of the buildings fell by levels under 50%. Moreover, the majority of the buildings showed their maximum value during the same month of January, which was a period before the outbreak happened in Spain, and five out of seven buildings had their minimum in the months of April and May, and the three following. Then all of the buildings increased their consumption during June and July, then they decreased in the summer break during August, and then, once the campus opened its door in September, the consumption went up again, showing that there is a clear correlation between the occupancy rate and the electricity consumption in this category.

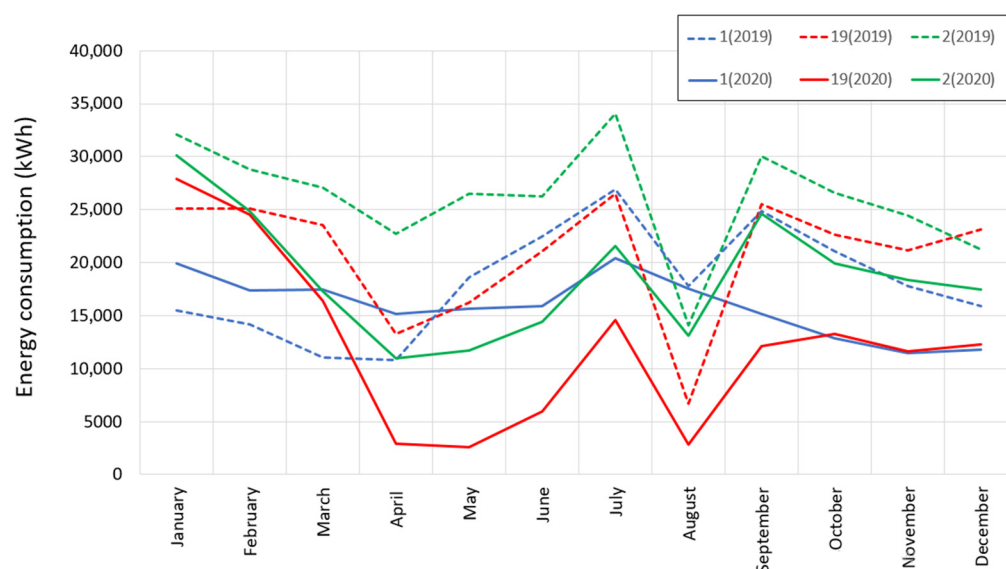


Figure 10. Energy consumption evolution of 3 administration buildings (2019–2020).

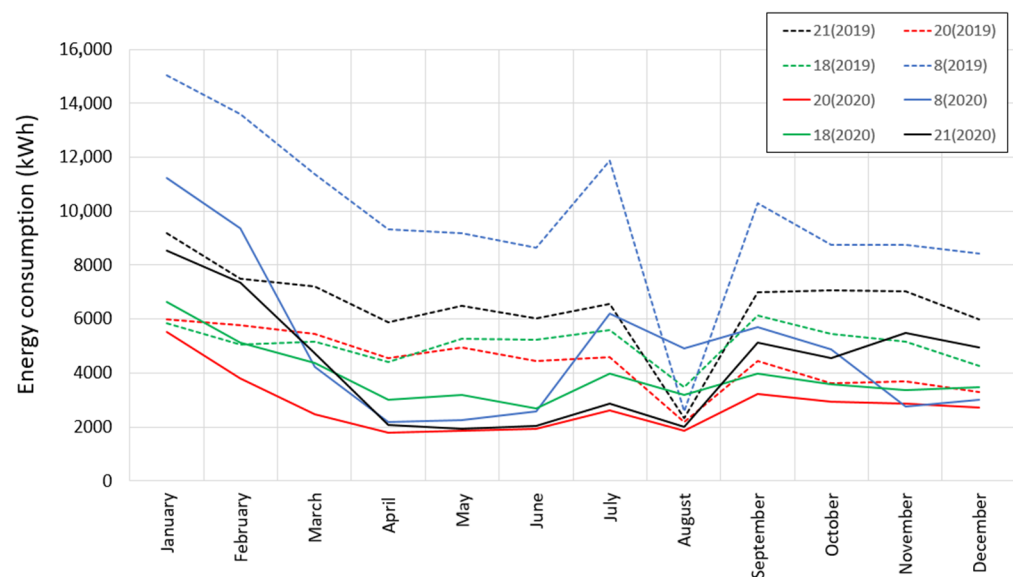


Figure 11. Energy consumption evolution of 4 administration buildings (2019–2020).

Table 4 presents the relative standard deviation monthly energy consumption in 2019 and 2020 (see data in Table 2). Generally, the year of the pandemic represented a much higher relative standard deviation than the previous year, except for building (1) which was also the least affected by the outbreak in the administration category and declined its consumption by only 12% in 2020. Building (19) had the highest relative standard deviation, followed by building (8), which makes them more likely to be considered the facilities most influenced by human activity within this category, and that is what the data (Table 3) confirmed since they fell by the largest shares of 41% and 50% in 2020, respectively. On the other hand, most of the buildings nearly doubled their relative standard deviation between 2019 and 2020, showing a coherence of the accumulated fluctuations rate inflicted by the COVID-19 outbreak.

Table 4. Relative standard deviation of the administration buildings category.

Building	Year	Max (kWh)	Min (kWh)	Average (kWh)	Relative Standard Deviation
1	2019	26,905.6	10,785.7	18,191.01	22%
	2020	20,395.7	11,439.4	15,890.7083	14%
2	2019	34,051.9	14,122.5	26,158.8083	14%
	2020	30,080.9	10,974	18,696.9333	24%
8	2019	15,021.7	2568.5	9818.08333	22%
	2020	11,217.60	2170.90	4935.55	43%
18	2019	6126.3	3480	5083.93333	10%
	2020	6632.8	2670.5	3880.51667	20%
19	2019	26,483.00	6714.40	20,839.93	21%
	2020	27,880.30	2561.60	12,247.03	77%
20	2019	5995.70	2178.50	4412.96	18%
	2020	5512.30	1771.20	2786.56	26%
21	2019	9166.50	2331.80	6,514.30	15%
	2020	8546.30	1928.80	4302.49	41%

Figures 12 and 13 illustrate the monthly energy consumption patterns of teaching facilities during 2020: the first one shows that buildings (5) and (15) had almost the same behavior during the year of the pandemic, and we can also clearly notice the correlation with the lockdown measures and the electricity consumption. During April, the energy consumption of the two buildings plummeted to levels of 17% and 15%, respectively. Compared with the level of the first month of January, buildings (5) and (15) began to steadily rise in June and July when few facilities were reopened as measures started to ease after the first wave of the pandemic. Then they decreased in August; however, they started to surge once again to reach a peak in October before they started to decline once again in November as the second wave hit the country. Building (4) energy consumption has declined by levels around 83% from January to April, and it wasn't until September when it slightly went up to get close to the levels of pre-confinement. This facility's overall electricity consumption declined by 57%, it was the most influenced building in this category during 2020.

Building (23) declined its consumption by 45% during the first confinement (January to April), slightly increased in May, then started to rise once again to peak in July, and remained relatively constant after September as its locals showed few practice activities with a limited number of researchers and students. Building (3) had a similar pattern evolution as (15) and (5), except for the difference in the October peak level, in which, in the case of building (3), the level surpassed the EC levels of the pre-confinement period. This rose the question of how a facility could consume more energy when its occupancy rate is lower than 50%.

Table 5 illustrates the relative standard deviation of the monthly energy consumption that varied within the range of 11% and 58% for every building in the teaching category. This indicator was higher in 2020 for most cases of this category, and that means that the majority of the buildings showed larger fluctuations of EC on a monthly basis in 2020. Data showed that buildings (5), (15), and (4) had major fluctuations by an indicator of 49%, 51%, and 58%, respectively. These buildings also had a major decrease on an annual basis (see Table 3). Buildings (3), (23), and (11) experienced minor fluctuations by an indicator of 19%, 14%, and 11%, respectively. These facilities also recorded closer EC values to the previous year, and that made them the least affected by the outbreak, and their share fell respectively by an annual margin of 13%, 8%, and 13%.

Figures 14 and 15 illustrate the monthly energy consumption patterns of research buildings in the research and laboratory category only fell by 2% in 2020; however, some of the buildings were affected by closing the campus during the outbreak period, and others were not. Building (13), which had a higher consumption than buildings (29) and (24) during January, fell in March and April to record a lower value than both buildings. Moreover, five out of eight buildings dropped and reached their minimum value during April, which was the following month of the lockdown. However, all the buildings seem to have their maximum value in July, except for building (9), and all of these peaks happened to be during a period of a very limited occupancy rate. The data showed (see Table 3) that the research and laboratory category was the least affected by the pandemic situation in 2020; the two buildings (30) and (24) even consumed more electricity than the previous year. Furthermore, those two facilities had the lowest fluctuations among the research category; their gap ratios between the maximum and the minimum consumption on a monthly basis were 9% and 25% during 2020, respectively, showing that, unlike most facilities, they kept a high and steady level of their EC. The electricity consumption of buildings (13) and (28) dropped from January to April by 43% and 53%, respectively. However, buildings (9) and (31) were most affected by the lockdown in this category, and their consumption on an annual basis fell by 10% and 11% between 2019 and 2020, respectively (see Table 3).

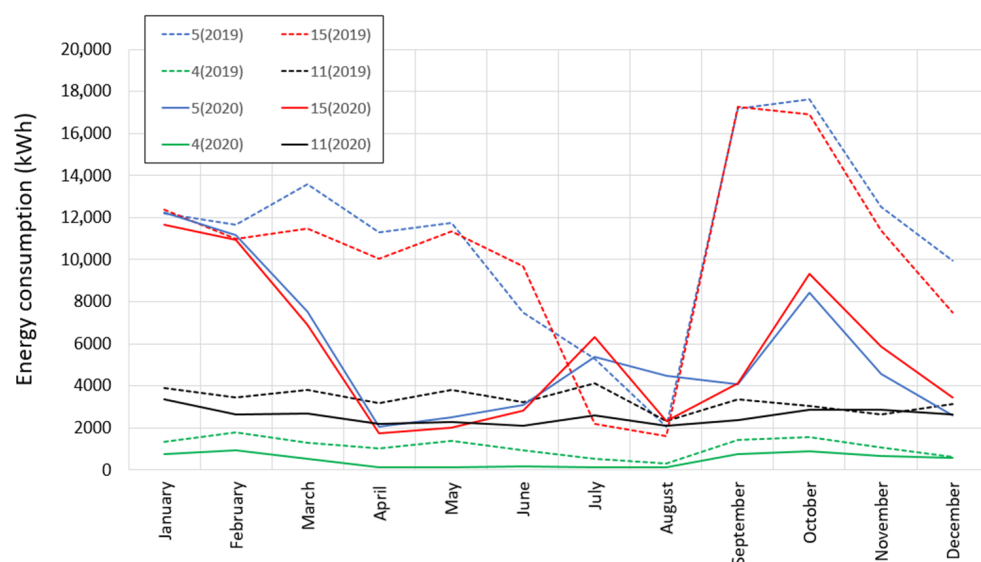


Figure 12. Energy consumption evolution of 4 teaching buildings (2019–2020).

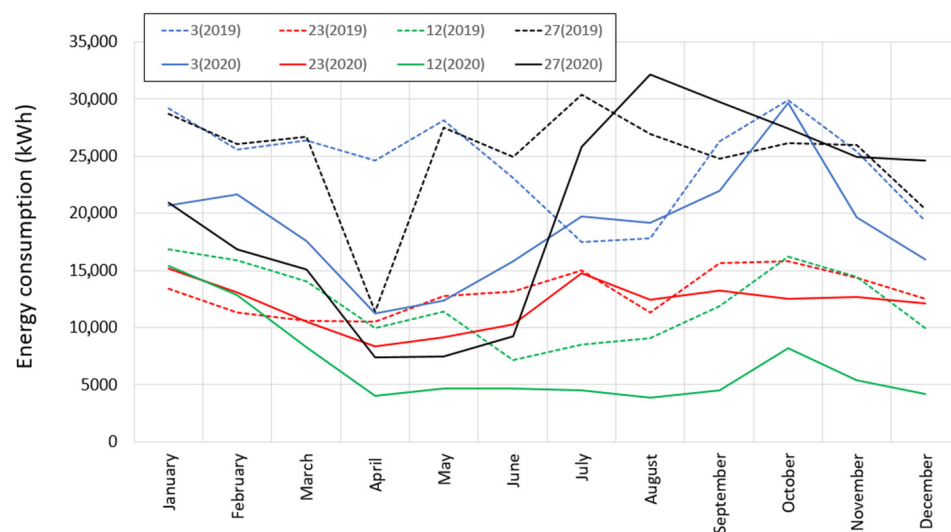


Figure 13. Energy consumption evolution of 4 teaching buildings (2019–2020).

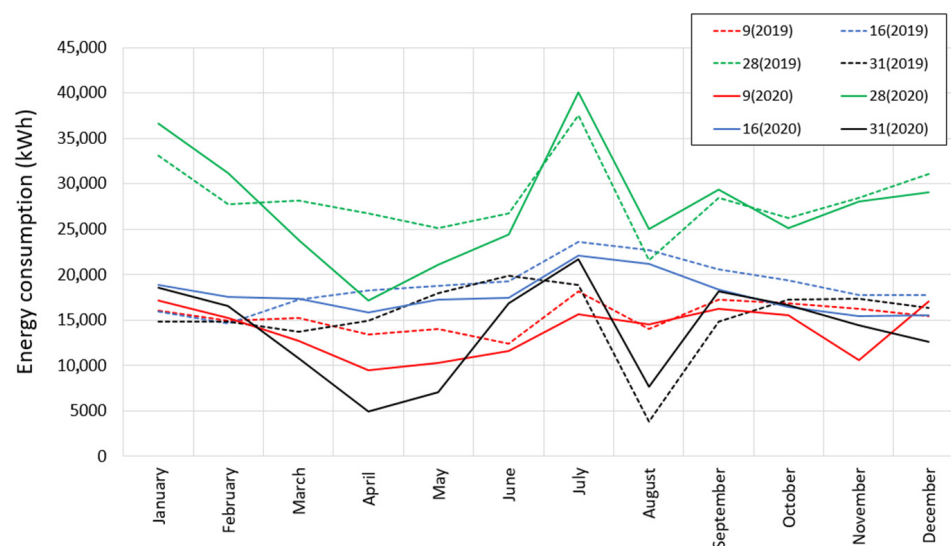


Figure 14. Energy consumption evolution of 4 research buildings (2019–2020).

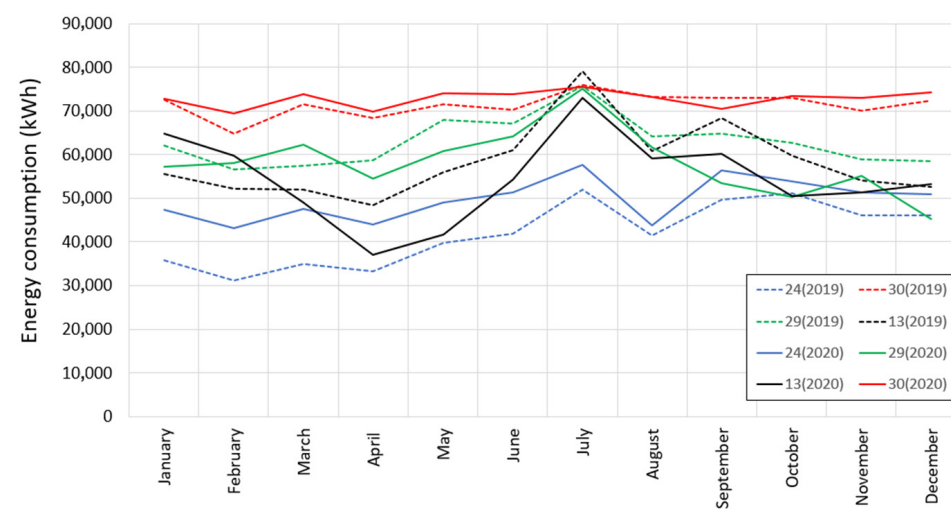


Figure 15. Energy consumption evolution of 4 research buildings (2019–2020).

Table 5. Relative standard deviation of the teaching and seminary buildings category.

Building	Year	Max (kWh)	Min (kWh)	Average (kW)	Relative Standard Deviation
5	2019	17,604.20	2067.60	11,041.25	30%
	2020	12,218.00	2058.40	5669.62	49%
3	2019	29,872.70	17,455.50	24,440.98	14%
	2020	29,668.40	11,203.80	18,787.90	19%
4	2019	1768.90	301.20	1105.22	32%
	2020	937.90	127.10	477.59	58%
15	2019	17,281.10	1602.90	10,227.97	33%
	2020	11,656.30	1726.10	5613.75	51%
12	2019	16,861.50	7188.80	12,113.98	23%
	2020	15,384.90	3866.10	6702.83	44%
27	2019	30,414.50	11,359.50	24,976.35	13%
	2020	32,172.60	7390.30	20,147.18	37%
11	2019	4133.20	2335.90	3335.29	12%
	2020	3367.80	2094.90	2559.81	11%
23	2019	15,838.00	10,547.40	13,036.79	12%
	2020	15,173.50	8323.70	12,031.78	14%

According to the deviation indicators developed in Table 6, research facilities had relatively low fluctuations that varied from 2% to 32%. Even though this category was different from others in terms of structural components and energy performance, the majority of buildings exhibited higher fluctuations in 2020 than in the previous year. The three buildings (16), (30), and (24) had a steadier pattern in 2020 than in 2019, according to their relative standard deviation, and, unlike other facilities, two of these three buildings increased their EC share in the year of the pandemic (see Table 3). The patterns of buildings (9) and (31) had the largest fluctuations in 2020, and they were the only buildings in the category that almost doubled their deviation indicators.

As Figure 16 showcases, building (26) showed large fluctuations in 2020. Moreover, during the period of January–April of 2020, library facilities fell by 85% and then increased in June and July to reach the first spike of 74% from the post-outbreak era of the level. Then its consumption dropped significantly during the summer break in August to get back in September to reach a second spike of 95%, which was the closest level to the pre-outbreak era in 2020. Table 7 shows that the library doubled its relative standard deviation and that it was among the most influenced buildings during the pandemic year: its pattern exhibited much more fluctuations in 2020 and its EC share on an annual basis declined by 44%.

The restaurant category was one of the most affected by the pandemic, and its electricity consumption dropped by 42% (see Figure 9). As Figure 17 illustrates, the monthly consumption evolution of both facilities was generally similar. Their EC level fell sharply to unprecedented levels: both buildings (6) and (33) consumed in April 7% and 42% of what they consumed in January, respectively. They kept a low level of EC until August when building (6) experienced a minor spike as the restaurant was gaining back activity, and in the following month of September, they started to raise their EC again due to the start of the new academic year. Table 8 showcases that they experienced a major increase in their monthly EC fluctuations. Building (33) raised its relative standard deviation from 11% to 29% and building (6) went up from 27% to 72%, which made it the most impacted building by the outbreak in this category. As the data in Table 3 confirm, building (33) since dropped its EC share by 42% against 37.

Table 6. Relative standard deviation of the research buildings category.

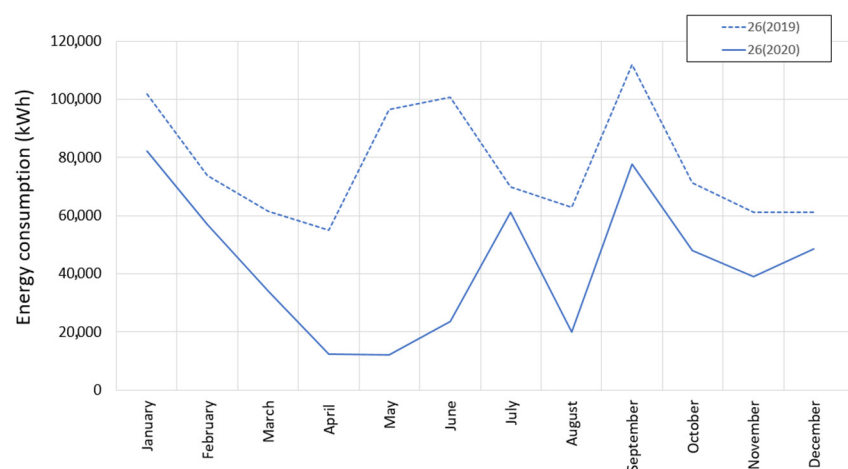
Building	Year	Max (kWh)	Min (kWh)	Average (kWh)	Relative Standard Deviation
9	2019	18,098.70	12,348.40	15,300.54	9%
	2020	17,186.50	9514.40	13,829.26	18%
28	2019	37,521.90	21,578.80	28,398.06	10%
	2020	40,093.20	17,159.70	27,583.87	17%
16	2019	23,590.20	14,611.10	18,810.87	10%
	2020	22,069.80	15,428.30	17,775.17	9%
30	2019	75,996.00	64,722.70	71,365.52	3%
	2020	72,688.40	72,688.40	72,688.40	2%
31	2019	19,832.80	3830.50	15,378.03	17%
	2020	21,635.00	4938.50	13,800.32	32%
24	2019	52,050.00	31,118.90	41,921.00	14%
	2020	57,599.00	43,088.80	49,721.68	8%
29	2019	75,815.30	56,529.50	62,892.18	7%
	2020	75,002.00	45,242.30	58,183.39	10%
13	2019	79,108.50	48,466.80	58,303.48	11%
	2020	72,961.00	37,050.60	54,483.53	14%

Table 7. Relative standard deviation of the library buildings category.

Building	Year	Max (kWh)	Min (kWh)	Average (kWh)	Relative Standard Deviation
26	2019	111,850.80	54,893.10	77,283.04	22%
	2020	82,203.40	12,147.60	42,962.44	45%

Table 8. Relative standard deviation of the restaurant buildings category.

Building	Year	Max (kWh)	Min (kWh)	Average (kWh)	Relative Standard Deviation
6	2019	8754.30	822.40	5814.98	27%
	2020	6328.60	323.20	2809.06	72%
33	2019	11,697.50	7873.50	9615.46	11%
	2020	10,491.30	3314.90	6032.70	29%

**Figure 16.** Energy consumption evolution of library building (2019–2020).

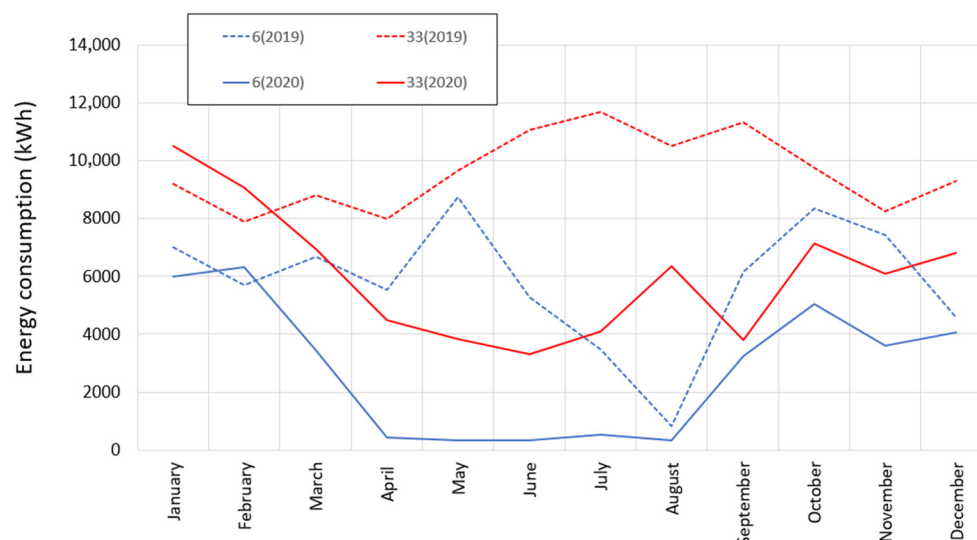


Figure 17. Energy consumption evolution of 2 restaurant buildings in 2019–2020.

Sports facilities accounted for 3 structures and, as Figure 18 shows, their EC patterns exhibited different trends through time: during the period of January–April of 2020, the three facilities (7), (10), and (17), respectively, declined by 71%, 60 %, and 46%. They all maintained a low level of EC in May, then building (7) significantly increased in June to reach pre-confinement levels in July as students were allowed to use the gym and the swimming pool. Building (10) slightly increased in June and July, but it wasn't until October when it regained pre-confinement levels. Unlike the previous structures, building (17) kept decreasing to reach a minimum level in August; then it started to rise again to reach pre-confinement levels in November.

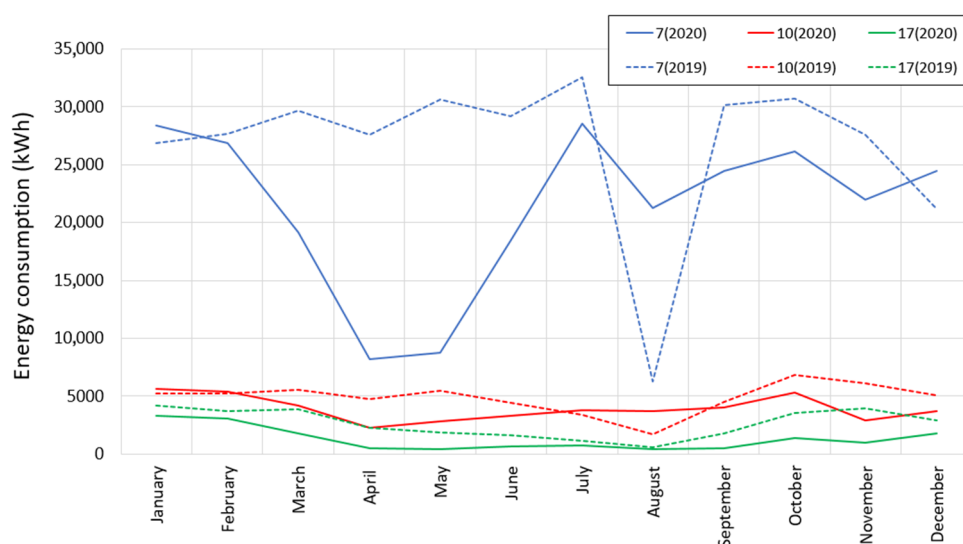


Figure 18. Energy consumption evolution of sports facilities in 2020.

The three facilities (7), (10), and (17) increased their relative standard deviation to 24%, 21%, and 62% (see Table 9), respectively, and they decreased their EC share on an annual basis respectively to levels of 80%, 81%, and 50%, in comparison with the previous year.

Table 9. Relative standard deviation of the sports facilities category.

Building	Year	Max (kWh)	Min (kWh)	Average (kWh)	Relative Standard Deviation
7	2019	32,554.10	6277.80	26,672.73	16%
	2020	28,536.60	8198.60	21,387.73	24%
10	2019	6869.90	1734.80	4852.76	14%
	2020	5637.40	2232.10	3920.06	21%
17	2019	4154.40	587.60	2609.81	41%
	2020	3321.50	417.50	1293.45	62%

4. Discussion

The campus's overall energy consumption dropped by 1.3 million kWh in the year 2020 due to the COVID-19 outbreak. This level of consumption was the lowest recorded in the last ten years. The research and laboratory was the only category that preserved its high consumption rate with an annual loss of only 2%. This goes back to the particularity of the research buildings that include different types of laboratories with heavy plug load materials that remain in operation regardless of the occupancy rate. Despite the fact that this category shrank on the macro-scale, on the micro-scale, buildings (30) and (24) increased their consumption share during the year of limited occupancy. Building (30), the data processing center of the university, is managed by a private entity: it has optimal conditions for this type of infrastructure both for electricity supply (double electrical connections, uninterruptible power supply system), air conditioning (conditions of adequate refrigeration) and for security (fingerprint and/or card access control, video surveillance cameras, fire and early response systems). This building provides services like hosting servers, so the larger part of the operation of this facility does not rely on the presence of occupants. Moreover, during 2020 the demand for the hosting service increased since many services and businesses had to go online because of the pandemic, which explains its high and steady energy consumption. Building (24) also grew its consumption during 2020 as this facility operates mainly for research purposes that cover diverse fields such as information technology, food science, biotechnology, and chemistry, and this research facility includes equipment with heavy plug load, and it was operating during the confinement due to the importance of their projects.

The buildings of the teaching and seminary portfolio had a significant drop in energy consumption amid the outbreak, except for the two buildings (3) and (23), and the reason behind this resistance is the special infrastructure of building (3) that includes an underground tank that collects the used water of the campus, and this structure uses a water pumping system to clear it out. During this period, building (23) was going through an expansion project which required the use of electricity by the construction company. We noticed that construction activities were allowed to operate during the first weeks of lockdown, and the construction sector was also one of the first sectors to get back to operation as the confinement measures started to ease.

The administration and offices category recorded a wide gap of ratios in the second month of the outbreak. This gap was mainly driven by building (1), which is the university presidency, where all the management decisions are centralized. This facility includes the security office that manages all camera recordings inside the campus, and this office stays in operation for the entire year. Furthermore, this facility remained operational at a minimum level during lockdown because of the crucial role that it plays in overseeing the whole institution.

The facility (7) energy consumption declined its EC share in 2020 by 20%, in comparison with the previous year. However, it is the one that decreased the most (by 71%) during April: during this month, the facility did not receive any students, and it recorded 8000 kWh, and later in the same year during August, it recorded 21,000 kWh when the facility was practically inoperative (see Table 2). This unusual trend motivated us to conduct

an inventory to understand the reason behind this disparity.

Building (10) shrank by only 20%, in comparison with the previous year, despite being unoccupied for three months and having a limited number of occupants during the rest of the year. The gym materials remained plugged in during the closing period, which represents an additional waste of energy that could have been avoided.

Restaurant buildings (33) and (6) patterns tend to have the same trends (see Figure 17). However, building (33) kept its level of EC above 3300kWh on a monthly basis (see Table 8) because it is a private entity that stayed in operation during the summer. It also kept its activity during the lockdown as restaurants were allowed to operate delivery services. On the other hand, building (6) was greatly impacted by the lockdown: its EC share plummeted by 93% in April, and it kept low levels until the reopening for the next academic year. It is also considered the facility that decreased second-most on an annual basis by 62%.

The library energy consumption was mainly influenced when its location was open for users. The energy consumption pattern (see Figure 17) has a correlation with the occupant activity; it fell by 85 % during the first lockdown and the summer break.

5. Conclusions

The situation of closing the campus facilities during the COVID-19 outbreak influenced the overall energy consumption of the campus. However, the impact magnitude varied from one category to another, and even some facilities among the same category represented a disparity and based on the data that we collected, we shone some light through this study on how the energy performance may be different from one structure to another. All the categories decreased their consumption value, and the majority of the facilities had a higher relative standard deviation in 2020 than in 2019.

The research category was the least influenced by the outbreak situation. This was due to the nature of how laboratory facilities operate: these facilities include equipment with heavy electricity load such as an ultra-freezer, incubator, hosting servers equipment, and graphic processing units for a supercomputer, and most of this equipment remained operational even during times when the campus was closed because they are part of ongoing projects.

The library was one of the categories most impacted by closing down during the outbreak, and this was due to the operating nature of this facility: it offers desk light and, to every student, electric outlets to plug in their own devices (computer, phone). In addition, there is centralized air conditioning in common reading rooms and areas, and all of these appliances were shut down, which drove down the electricity consumption.

Efficient management could help reduce energy consumption by an important margin. Promoting energy-saving habits like unplugging unused appliances could reach 10% in some cases [28,29]. In our case study, after analyzing the patterns and conducting inventory in the University facilities, energy-saving measures such as switching off water heating systems in sports facilities for the swimming pool and showers and unplugging all the computers and other unused appliances such as vending machines during the time when the University locations are inoperative (confinement, summer break . . .) could have an important impact on energy savings in the future.

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